DOCUMENT RESUME

ED 339 353 IR 015 299

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TITLE Strategic Computing Directions and Opportunities for University-Government-Industry Partnerships at the University of Saskatchewan: Preparing for the Twenty-First Century.
PUB DATE Mar 90
NOTE 36p.
PUB TYPE Information Analyses (070) -- Viewpoints (Opinion/Position Papers, Essays, etc.) (120) -- Reports - Descriptive (141)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Computer Networks; *Computer Uses in Education; Databases; Educational Administration; *Educational Technology; *Financial Support; Foreign Countries; *Government School Relationship; Higher Education; Information Networks; Institutional Research; Library Networks; Mission Statements; Research and Development; *School Business Relationship; Telecommunications
IDENTIFIERS *University of Saskatchewan (Canada)

ABSTRACT

This report is intended to serve as a focus for developing a commitment for continuing investment in computer support for education, research, and administration at the University of Saskatchewan. Based on the assumption that effective utilization of computers, computer networks, and other telecommunications technology is essential to the fulfillment of university education and institutional research, this report discusses the following: (1) educational challenges for the 1990s, as they relate to the use of computers; (2) the need for a variety of computer applications in education, research, and administration, including information networks, database access, and library networks; (3) the University of Saskatchewan Ethernet computing model; (4) computing initiatives for the university to undertake in education, research, and administration; and (5) long-term, cooperative relationships between the university, the government, and business and industry in order to achieve university goals in a cost effective manner. An executive summary is provided and references are cited throughout the report. (DB)

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Strategic Computing Directions and Opportunities for University-Government-Industry Partnerships at the University of Saskatchewan:

Preparing for the Twenty-First Century

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March, 1990

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Executive Summary

Education is a nation's best investment. It improves the abilities of the nation's most valuable asset, human resources. Japan has demonstrated that a highly educated workforce affects a nation's economic and social prosperity more than any other resource. Major improvements in education are being advocated in the United States by government, industry and educators as the primary means to maintain or improve their standard of living. Educational institutions and governments in all countries must meet the demands for a better quality education, even in the current difficult financial times.

Computer and communications technologies are an integral and important part of a modern university. The effective utilization of computer based tools is essential to the fulfilment of a university's education and research missions, as well as to support its administrative needs. The importance of these tools will continue to grow in an increasingly technological world. Continuing investment in these technologies is critical to the success of the University of Saskatchewan.

Our university, like many other similar institutions, is strongly challenged by legitimate needs for computer equipment, support and application development. Current funding levels for either capital or operational support for computing can not meet these needs. In addition to seeking increased support from its traditional funding sources, the University must turn to 'partnerships' with industry and government for financial assistance.

Industry partnerships are becoming increasingly difficult to secure. This is due to increased competitiveness between universities and a declining amount of industry resources available for supporting education. As a result, it is imperative that we identify strategic areas of computer development for the campus and concentrate our limited resources in these areas. The strategic areas chosen must include ones in which the university has significant expertise and which hopefully will benefit industry in exchange for their support. Our commitment to specific areas of development is the pre-requisite to discussions with industry, in seeking external support.

This document:

- outlines education challenges for the 1990's, as they relate to the use of computers.
- highlights the need for continuing investment in computer technology by discussing a variety of computer applications in education, research, and administration.
- describes the University of Saskatchewan computing model.
- suggests strategic computing initiatives for the University to undertake in education, research and administration.
- proposes long-term, co-operative partnerships between university, government and industry to achieve the University's goals in a cost-effective manner.

It is hoped that this document will serve as a focus for developing a commitment for continuing investment in computer support for education, research and administration at the University of Saskatchewan.

1. Introduction

The importance of education to a country's economy and standard of living is expressed by the M.I.T. Commission on Industrial Productivity:

> "The most important investment in the long run is in the nation's schools. ...Without major improvements in primary and secondary schooling, no amount of macroeconomic fine-tuning or technological innovation will yield a rising standard of living."[1]

The use of computer technology is a critical factor in modern education. Excellence in education and research is dependent on excellence on computing (but not only on computing). This does not mean that computing is the only prerequisite to high quality education, but that high quality education in most disciplines can not be delivered without the use of appropriate computer based tools.

The University of Saskatchewan, if it intends to offer a relevant educational experience, must continue to incorporate computer based tools in our teaching, research and administration. Not unlike many similar institutions, we are strongly challenged by the legitimate needs for computerization and support for computer developments. The demand for these tools is growing rapidly within all areas in the university and is placing new financial demands on our university, as it is throughout North America. These costs prompt worries about creating inequities in the opportunities provided to students by "have" and "have not" institutions.

Our university has a significant investment in computing technology, but we also have a continuing need to invest further in computing applications that improve our teaching, research and administration. While we have not invested as much as many other institutions our size, we believe that our computing environment is a show-place of cost-effective, network-based computing on a campus-wide scale. The University of Saskatchewan is in a unique position in Canada to be able to deliver this computing environment. Our advantage and strength in computing is our campus-wide network and the resources it provides; we have had over 4 years of experience implementing our networked computing environment while other universities are only now beginning to build such a network. We need to build upon our strengths.

This document attempts to identify areas of need for additional investment in computing activity, in a framework that would encourage university-industry cooperation in joint development projects. That the University must continue to vigorously seek strategic partnerships in areas like computing is abundantly evident by the demands for computing applications in relation to our available resources. From the industry side, we are in a period of serious competition among academic institutions for declining support from computer manufacturers, and manufacturers are demanding more tangible benefits from their alliances with universities:

> "Relationships between research schools and IS suppliers don't simply involve equipment donations anymore. More is demanded from these alliances.[2]"

Thus the University, if it is to sustain its investments and continue to employ appropriate computer applications, must be mindful of its needs in the context of opportunities to recruit industrial assistance, in an increasingly competitive and restrictive environment. This does not mean that we choose our strategies on the basis of opportunity to obtain external assistance in their implementation; our priorities must be <u>our</u> priorities. However, wherever we can identify an

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[1]Berger, Suzanne, Dertouzos, Michael L., Lester, Richard K., Solow, Robert M. and Thurow, Lester C.; "Toward a New Industrial America", Scientific American. June 1989, Volume 260, Number 6, pp. 39-47.
[2]Davis, L., "The University Connection", DATAMATION, Sept. 15, 1989, pp 69-72.

institutional requirement for computing that may match an interest from the manufacturing community, we need to consider our options to attract outside assistance to achieve an objective which is a priority to the University.

During the period 1985 to 1988, the University of Saskatchewan participated in the Campus-Wide Investment Program of Digital Equipment Corporation. In this partnership the University committed to a number (approximately 22) of individual projects ranging from building teaching labs to developing new administrative applications, all building upon a campus-wide Ethernet network. Our faculty and staff who participated in the program acquitted themselves well, and this good reputation is a valuable legacy of the project. Thus we have solid experience in obtaining a partnership agreement and carrying out our commitments within such a project.

In an attempt to develop one or more partnerships with the computing industry, the Department of Computing Services has identified a number of categories of what we feel are areas of important computing needs at this university. This set of possible developments, presented in Appendix I, may be incomplete, but it can serve as an excellent base for considering additional areas that may have been overlooked. As appropriate groups within the University examine these areas and determine some sense of priorities for development, we can spin off specific projects to develop in cooperation with vendors. Thus the purpose of this document is to focus consideration of strategic needs for computing investment on campus, and to identify projects within our requirements that can attract external investment.

2. Why Computing is Strategically Important in a Modern University

2.1 The Information Explosion

Information processing and distribution are vital components of university education, research, and administration. University students, faculty, researchers, administrators, and support personnel are being challenged to process more information, and in shorter time periods. Futurists predict that this information explosion will continue and even increase:

- The amount of information is growing at an accelerating rate. The information base is estimated to be doubling every 2.5 years[1], and in certain disciplines every 1.5 years[2].
- Knowledge is becoming obsolete more rapidly. Hallett estimates that less than 10% of our knowledge today will be useful in our careers twenty years from now[3].
- There is a growing need, by organizations and individuals, for the most current information.
- There is increased demand for individuals with a wide range of skills and interdisciplinary knowledge.
- Individuals entering the workforce for the first time in the 1990s can expect to change careers three to five times in their lifetime; each change will require a different information and knowledge base.

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[1]Hallett, Jeffrey J., "Worklife Visions - Redefining Work for the Information Economy", American Society for Personnel Administration, Alexandria, Virginia, September, 1987.
[2]Ogden, Frank. Address to DECUS Conference, Vancouver, Canada, February, 1989
[3]Hallett, Jeffrey J., Guest speaker at a Digital Equipment sponsored seminar, Saskatoon, June, 1988.

- There are rapid changes in the nature of jobs. Hallett notes that 50% of the jobs being performed in 1987 did not even exist in 1897, and estimates that 1/3 of all jobs being performed in 1987 will be obsolete by 1992[1]. This trend is visible in the changing responsibilities of clerical workers.

- There is a growing need for fast information exchange and communication on a global basis.

2.2 The Computer as a Communications and Information Processing Tool

Computers today are surpassing their traditional roles as computation and word processing tools, and are becoming important communications and information processing tools. The use of computers in this new application will continue to grow to meet the demands of a rapidly changing, information based and global society.

As a communications tool, computers minimize the barriers of time and location. Information can be quickly exchanged between individuals at remote locations; the sender and receiver can participate in the exchange at their convenience. As an information processing tool, computers already have the ability to store, organize, search, present, distribute, and share information.

Emerging technologies, such as hypertext, CD-ROM, voice synthesis and recognition, visualization, artificial intelligence and executive information systems will further enhance the computer's abilities, especially to manipulate multi-modal information: text, numbers, graphics, audio and video. Additionally, as financial restraint imposes increasing pressures, computer systems will be essential to 'doing more with less' in all aspects of the operation and administration of our educational institutions. Computer technology continues to offer improved cost effectiveness through lower prices or increased performance[2].

Computer-based tools perform repetitive and routine information processing tasks, more effectively and efficiently than would otherwise be possible. Individuals are free to concentrate on the creative and innovative tasks only they can do. Computer-based tools "leverage the full talents"[3] of today's knowledge workers, expand their capabilities, and raise the significance of their contributions. John Sculley, President of Apple Computer Inc., discussed this new role for computers, at an address to a thousand educators, business people and government officials[4]:

> "Originally, computers improved worker's productivity by helping them get tasks done faster. But the real productivity gains will come by empowering individuals to work better, not just faster. What's needed are tools to help change the way they work, the way they think, the way they communicate and even change the way they learn."

The importance of computers in all areas of a university is evident in the remarks of the computer advisory committee at the University of Calgary[5]:

> "the availability and use of appropriate computing technology is the most important single tool available to the University for achieving effectiveness and efficiency in carrying

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[1]Hallett, Jeffrey J., ibid.

[2]Three years ago, desk-top workstations capable of processing 1 MIPS (million instructions per second) cost about $10,000. Today, $10,000 can buy workstations capable of over 10 MIPS. This is expected to increase to 50 MIPS by 1992 and over 700 MIPS by the end of the century. However, total computing costs are rising due to increasing hardware, software and support demands.

[3]Leibs, Scott. "Innovation Through Integration", DATAMATION. January 15, 1990. pp. 60-68.

[4]Edeburn, Mary; "Apple CEO John Sculley says U.S. education must compete for 'share of mind'", Articles database of CCNEWS, the Electronic Forum for Campus Computing Newsletter Editors, a BITNET-based service of EDUCOM.

[5]"Computing Strategies for the University of Calgary", The GFC Telematics Committee, Jan. 23, 1987.

out its teaching, research, and administrative responsibilities. Indeed, it is likely that the future of universities will be more dependent on the successful application of computing technology than on any other single factor ".

Without access to appropriate computing tools, our students, faculty, researchers, administrators, and support personnel will be seriously disadvantaged. The University must enable its employees and students to reach their full potential.

The following subsections briefly examine the application of computers in all areas of university operation: instruction, research, and administration.

2.3 Computers in Education

The University's primary mission is education and research. Like other universities, we are facing calls to alter the content and emphasis of university level education and research[1]. Some of these demands for change include the provision for:

- greater concentration on science and engineering education, but also in the humanities, international studies, and global consciousness.

  The MIT study shows that only 6% of U.S. baccalaureates are in Engineering programs compared to 20% in Japan and 37% in West Germany. The Canadian figures are about the same as the U.S., while the Saskatchewan figures are lower[2]. It is also felt[2] that non-science majors should take a greater core of science classes, and that science, business and engineering majors should devote more time to the study of foreign languages, cultures, history, politics, legal systems, market customs, tastes, regulations, and foreign business practises.

- specific career training, but also a 'general education'

  On the one hand, universities are facing pressure from industry and the declining economy to provide highly skilled graduates. This training is essential in professional colleges and disciplines such as Medicine, Engineering, Law, Computer Science, Education, and others. On the other hand, it is realized that universities can not provide graduates with all the information and knowledge that they will need for a lifetime, and the best that we can do is to teach interdisciplinary skills, flexibility, problem-solving, critical thinking, a commitment to life-long learning, and how to learn. Peter Drucker, a noted author on economics, politics and society writes[3]:

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[1]Dertouzos, Michael L., Lester, Richard K., and Solow, Robert M., "Made In America, Regaining the Productive Edge",The MIT Commission on Industrial Productivity, MIT Press, Cambridge, Mass., 1989.

[2]Statistics Canada, "Universities: Enrollment and Degrees", Catalogue number 81-204, for 87-88 academic year.

[3]Drucker, Peter F., "The New Realities", Harper & Row, Publishers, Inc. 1989.

"The knowledge society requires that all its members learn how to learn. It is by the very nature of knowledge that it changes fast. Manual skills change slowly. Socrates the stonemason - the trade in which he made his living - would be at home in the modern mason's yard. But Socrates the Philosopher would be totally baffled by both the concerns and the tools of such key disciplines of modern philosophy as symbolic logic or linguistics. Engineers ten years out of school are already 'obsolescent' if they have not refreshed their knowledge again and again. And so are the physician, lawyer, teacher, geologist, manager, and computer programmer. Furthermore, there is an infinity of knowledge careers to choose from. There is no way in which even the best school system with the longest years of schooling can possibly prepare students for all these choices. All it can do is prepare them to learn. The post-business, knowledge society is a society of continuing learning and second careers."

- development among students of both individual and collaborative work skills.

  The business and work environment of the future will depend greatly on collaboration between university, industry, government and labour. Graduates must possess both collaborative and entrepreneurial work skills.

- greater accessibility to quality education, on a life-long basis, and including higher participation from lower income families, minorities and women.

- a basic level of computer literacy. Regardless of discipline, today's graduates must be competent in a world that is increasingly technology-based. Peter Drucker writes[1]:

  "Since school learning and school diplomas increasingly control access to jobs, livelihoods and careers in the knowledge society, all members of society need to be literate. And not only in 'reading, writing, and arithmetic.' Literacy now includes elementary computer skills. (underlining added) It requires a considerable understanding of technology, its dimensions, its characteristics, its rhythms - something almost totally absent today in any country."

- greater emphasis in the study of environmental issues, ethics, social justice and other social values and the integration of this study into disciplines such as business, science and engineering. Future leaders and citizens will have to make responsible decisions regarding scientific progress and society's long term survival.

Computers must play an important part in meeting these educational demands. Information, which is up to date, easy to use and widely accessible is crucial to providing better educational content. As more information becomes available in electronic form, computing resources will become essential to access, analyze and distribute it.

If the library is the 'heart' of a modern university, then surely the campus computing and communications systems are the 'nervous system'. Continuing investments in computing are inevitable and essential to provide the best educational opportunities to our students. In reporting on a recent study of the State of Texas educational system, H. Ross Perot, the task force chairman, declared that our investments in education should be directed to those areas that "allow our children to achieve their fullest potential"[2]. Computer technology is an important enabling technology that enhances a student's ability to acquire, organize and analyze information, not only while in school, but throughout their working careers.

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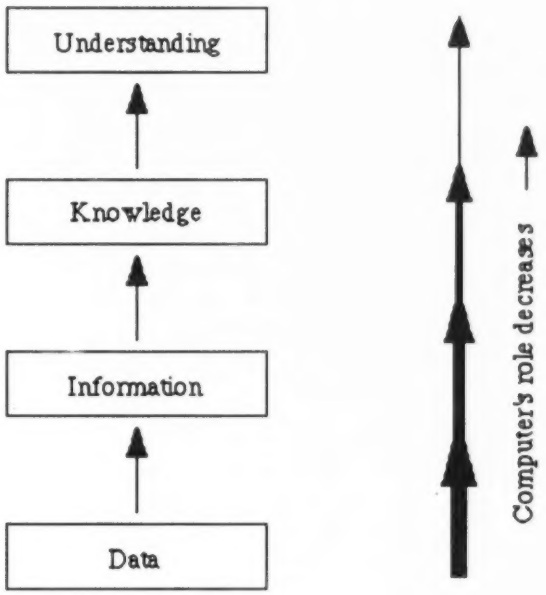
[1]Drucker, Peter F., ibid.
[2]Perot, H.R., "Public Education", address to EDUCOM '88, Washington, D.C., October 25-28, 1988.

The following diagram shows various levels of learning and their relationships. Higher levels of learning are reached by "processing" of the lower levels. The computer's role in each of the learning levels (in order from the bottom to the top) is shown as it relates to:

- data acquisition and analysis (lowest level).
- analysis, storage, retrieval, sharing and distribution of information, which has been derived by processing data.
- knowledge which derives from access to information and additional processing of it (usually by human 'processing', but perhaps by new computerized 'knowledge-based systems' or 'expert systems').
- understanding of our complex world of physical, socio-economic and human phenomena, which may be assisted by computer simulation, modelling and visualization.



If it is not the case already, it is predicted that computers will soon "out-perform" humans in the areas of data and information processing. The advent of new, easy to use, powerful software tools for simulation, expert system development, natural language processing, computer based education and visualization will continue to increase the computer's role in education, as we seek understanding of our increasingly complex world.

The strategic importance of computers in the educational process is probably best visible at Carnegie Mellon University (CMU). For several years now, CMU has stressed that excellence in education is dependent on excellence in computing. (This does not mean that computers are the only prerequisite, but that they are essential tools necessary to achieve high quality university education and research.) Today, CMU has about 11,000 computers connected in a network and

used in all disciplines. In Canada, The University of British Columbia computer advisory committee states:

> "In this era, the correlation between excellence of scholarship and excellence of the academic computing environment will become stronger..."[1]

The uses of computing technologies for university education are numerous. Some current examples at our institution can demonstrate:

- development of basic computer literacy. Students in virtually all disciplines are expected to be able to use computers to acquire and analyze data, prepare class reports and to communicate electronically in performing these tasks. Our library catalogue, for example, cannot be accessed without using a computer terminal to search for materials. Computer based tools are today widely used for writing, performing numerical calculations, graphics, communications, preparing presentations and drafting.

- increased accessibility to the University. A pilot project in distant education (off-campus instruction), in 1988-89, used computers to communicate between students and faculty, as well as to exchange assignments. This method was quicker than using mail services and, for some communications, more convenient than telephone.

- improved communications. Electronic mail is regularly used in many classes to support communications between faculty and students and to exchange assignment information.

- students using remote electronic information databases. Students in the College of Law access Canadian legal information databases such as QUIC/LAW[2] and CAN/LAW[3] for legal research classes.

- computer-based simulation. Chemistry and Chemical Engineering students model some molecular reactions and experiments using computers rather than in the laboratory; computer simulation is easier, less costly, and safer. Without computer simulation, some experiments could not be undertaken. Simulation is also used to study biological phenomena, geological systems, agricultural economics, engineering projects, veterinary diagnosis, educational administration, medical applications and many others.

- computer-based laboratory tools. Computers are becoming an essential part of most science laboratories, either as an integrated component of the lab equipment or as stand-alone "assistant". They are commonly used in Biology, Chemistry, Physics, Engineering and other campus labs.

- computer applications in the Humanities and Social Sciences. Students in the College of Arts and Science use computer-based style and grammar analysis tools to improve their writing skills. Both English and French word processing tools are also used. A database of news clippings about Soviet-China relations is used in a Political Science course. Students in Psychology can explore course concepts by using simulation software which comes with the textbook. Computer-based music tools are used at many universities for music composition, music theory, basic

[1] "Academic Computing Platforms and Services in the 1990's", The Report of the Task Force on Service Platforms, Computing Centre, University of British Columbia, Draft 12, January 10, 1988.
[2] QL Systems Ltd., Kingston, Ontario.
[3] Canada Law Book Inc, Aurora, Ontario, and Canada Systems Group, Ottawa.

harmony, music history and ear training. Our Music Department is hoping for funds to establish a computer-based music lab.

- classroom teaching with computers. A computer with an attached data projector can be used in a classroom as an electronic blackboard; whatever appears on the computer monitor is also displayed on an overhead screen. This technology was used in a mathematics class to demonstrate course concepts and to provide training in the use of computer-based mathematical tools.

- providing new ways to 'navigate' multi-media information sources. The colleges of Dentistry and Education are exploring the use of tools such as HyperCard[1] to provide students access to multi-media information - text, graphics, video, and audio - from an optical disk attached to a computer. These tools are used at other universities as content material for complete classes.

- developing professional competence in computing-intensive professions. Colleges such as Commerce and Engineering cannot now graduate a student who is not intimately familiar with discipline-specific computer tools: accounting, management, the design of structures, electronics and mechanical systems, computer programming and systems design. We have a critical and demanding requirement to provide students with an experience base that is compatible with the rapidly changing requirements and technologies found in industry.

We need to recognize that the ability to provide students with a sound background in the use of computers, in virtually every discipline, is now a firm requirement in post-secondary education. In fact, the quality of computer support at an institution is now one of the most critical determinants of recruitment success for both students and faculty in North American universities. Although much progress has been made at the University of Saskatchewan, in catching up to the facilities at similar Canadian universities, this is an area that requires continuing investment if we are going to provide students with the tools that they need in order to contribute through successful careers in today's world.

2.4 Computers in Research

Basic and applied research have always been essential components of a university environment. The benefits of university research include improved instruction, new products and processes, applied research results for industry, and direct and indirect economic benefits to the communities that they serve.

Most university research depends heavily upon computing support. The data processing demands in a research environment are very great; as soon as additional capacity is available, it is consumed by the latent demand in the hundreds research projects on campus. The ability to perform research in many areas is limited by computing access and processing capacity: at this campus, some contracts with provincial industry have had to be declined for lack of computing facilities.

As in instruction, computers are used virtually in every research discipline. Thus, a modern university cannot perform its research role without access to a range of computer systems. The demands for additional processing power at universities are always led by the research enterprise of each institution. Hence, the availability of up-to-date and functional systems to support research is a

[1] Apple Computer Corporation, Cupertino, California.

critical requirement at this and other campuses. The following statement from the Senate Committee on Computing, Tulane University, demonstrates the importance of computing to university research:

> "The academic reputation of a university will depend to an increasing degree on its computing resources because they directly affect its ability to attract the best faculty and students. A strong computing system is an indispensable (underlining added) part of achieving our university goal of a high quality research university."[1]

There are many areas of computer-based research at our campus that have tremendous importance to provincial industries and to the quality of life of our citizens. To cite some examples:

- The flooding of the potash mine at Esterhazy was nearly a billion-dollar loss to the provincial economy; the application of seismic data processing techniques developed in the Department of Geological Sciences could prevent such disasters. The Department is also conducting research in the use of computer-based tools to locate ore and petroleum deposits.

- The Saskatchewan Institute of Pedology has a comprehensive data bank of soil characteristics throughout the Province. Computer-based systems, designed for that purpose, can make this information available throughout the Province so better agricultural practises can be identified for the farming industry.

- Researchers in the Department of Biochemistry use computers extensively to analyze X-ray diffraction data from protein structures. This study, protein crystallography, is important in the design of new drugs and protein structures and in understanding how the body's immune system works to fight diseases like cancer. A new computer program recently made a breakthrough in a research problem that was previously unsolved after two years of attempts using traditional methods; this program used over 220 hours of computer processing. Due to heavy system loads, this requires 1 to 2 months to complete during the regular school year. The analysis of larger protein structures requires about 10 times more computer time; research projects with these larger molecules can not be undertaken presently because of the lack of higher-speed computation resources.

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[1] "Tulane Computing for the 1990's, Long Range Planning Report of the Senate Committee on Computing", Tulane University, April 20, 1988.

- Chemistry is no longer done exclusively in a test tube. Computers are used for molecular design, to model chemical reactions and for molecular engineering. These techniques are currently used by Dr. Paul Mezey and his group in the Department of Chemistry[1] for drug design, but they could be extended to herbicide and pesticide design.

- The department of Electrical Engineering uses computers to study the behaviour of electrical power generation systems, and to design systems that are more stable and reliable.

- The College of Engineering is doing research which is leading to better aerodynamic shapes for automotive vehicles. College-designed "super mileage" vehicles have won several North American championships. The Nexus vehicle built by the College was tested using a computer-supported wind tunnel, designed using computer graphics, and the structures analyzed using a finite element computer program.

- Image and digital signal processing is inherently compute-intensive. Research projects under way on-campus include farm implement guidance, robot vision, satellite imaging and medical diagnosis.

- The University of Saskatchewan Library is developing an on-line data base of bibliographic information that is available both on- and off-campus. Access to other bibliographic databases is available from CD-ROM's or from on-line searches to database providers. These services are important to researchers in many disciplines.

- Humanities research, such as natural language understanding as well as semantic and syntactic analysis of writing, requires access to electronic databases of literary works. The use of scanners to create electronic forms of written text is increasing.

- External networks are heavily relied upon by researchers for communication and exchange of information. Some examples include: VLSI designs created in an Electrical Engineering class are transmitted electronically to the Canadian Microelectronic Corporation in Kingston, where they are made into integrated circuits; a French word frequency list, created at the University of Chicago, was transmitted electronically to this University and will be used to develop a French dictionary for word processing; the University receives a large number of software packages electronically from other universities at minimal or no cost; researchers have used network facilities to access specialized facilities such as the University of Toronto supercomputer, without having to leave campus; campus faculty use external networks in a variety of collaborative research projects.

- Research is under way to create an interactive multi-media database on contemporary French-Canadian culture and civilization. This database will contain textual, visual, and audio information, and can be used for teaching, self-instruction and reference, in provincial and Canadian classrooms.

- Research in computer speech and computer-based learning is being conducted as a means to assist kindergarten children who show early signs of possible reading problems, so that they can avoid developing future reading failure.

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[1]Dr. Mezey has recently received his second Strategic Operating Grant from NSERC. No other theoretical chemistry group in Canada has yet received a first strategic grant.

- A computer-based system developed in Veterinary Medicine electronically distributes laboratory test results to Veterinary practitioners in the prairie provinces more rapidly than was possible with services based on conventional mail services.

- The Saskatchewan Linear Accelerator Laboratory uses computers in all phases of the design, operation and data analysis in the facility; this world-class laboratory conducts important research in the study of molecular and atomic structures.

- Computers are used to analyze the performance of athletes, in the College of Physical Education and to study the effects of life style on health.

There are many other examples of computer-based research that could be listed. A modern university simply cannot sustain its research role without computational support systems. Research computing needs are among the most demanding computer applications at a university. Continuing investments are necessary in order to allow our researchers, and hence the industries that depend on that research, to remain competitive.

The following is a partial list of the provincial, national and international organizations with whom University of Saskatchewan researchers are currently working, either through research grants, collaborative projects or contracts for research. The full list currently includes 198 agencies[1]
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Agriculture Development Corporation of Saskatchewan
Agriculture Canada
Alfred P. Sloan Foundation
Anheuser-Busch Companies Inc.
Cameco
Canadian Microelectronics Corporation
Canadian Fitness and Lifestyle Research Institute
Chevron Corporation
Connaught Labs
Deere & Company
Dow Chemical Canada Inc.
Energy, Mines & Resources Canada
Federated Cooperatives Ltd.
Imperial Oil Ltd.
International Minerals & Chemical Corporation
Max Bell Foundation
Merck Frosst Canada Inc.
Molson Breweries of Canada
National Research Council
North Atlantic Treaty Organization
Ontario Ministry of Agriculture and Food
Quaker Oats Foundation
Saskatchewan Parks, Recreation & Culture
Saskatchewan Lung Association
Saskatchewan Research Council
Saskatchewan Health
Saskatchewan Government Insurance
Saskatchewan Council
Saskatchewan Water Corporation
Saskatchewan Power Corporation
Saskatoon Separate School Board
SaskTel
Social Sciences and Humanities Research Council
State of Florida Department of Citrus
Upjohn Company of Canada
World Bank
Agriculture Development Fund
Alberta Oil Sands Technology & Research Authority
Amok Ltd.
Atomic Energy Canada Ltd.
Canadian National Railway
Canadian Energy Research Institute
CIDA
Ciba-Geigy Canada Ltd.
CP Rail
Develcon Electronics
Eli Lily
Esso Petroleum Canada
Health and Welfare Canada
Industry, Science and Technology Canada
Kidney Foundation of Canada
Medical Research Council
Mitel Corporation
Monsanto Fund
Natural Sciences & Engineering Research Council
Northern Telecom Canada
Potash Corporation of Saskatchewan
Sask Sport
SSTA
Saskatchewan Pulse Crop Development Board
SMDC
Saskatchewan Agriculture
Saskatchewan Education
Saskatchewan Heart Foundation
Saskatchewan Energy & Mines
Saskatchewan Science & Technology
Saskatoon Public Board of Education
Smith Kline Corporation
Sport Canada
Transport Canada
Western Grains Research Foundation
World Wildlife Fund Canada

2.5 Computers in Administration

[1]Complete listing obtained from Muir, R., Director of the Office of Research Services, U. of S., December 20, 1989.

The university's business needs are not unlike those of other large organizations, who depend on the effective utilization of computer technology for operation, planning and administration. On any given work day, hundreds of staff use computers to manage the information that controls the many activities of the institution. Automation is now very important as a tool to 'do more with less'. For example:

- the expansion of Alumni Development activity would be impossible without computer systems to maintain information on past and potential donors.
- the recently developed Student Information System extends new and better services to students and College offices, without an increase in staff.
- the University Library would have to close its doors if it did not have computer support systems to facilitate access to the approximately one million items in the campus collection.
- computers have played an essential role in the reduction of the energy consumption of the University, estimated at approximately 45% over the last two decades.
- a skills database being developed in the College of Graduate Studies and Research will help "match" research opportunities with researchers.
- word processing and desktop publishing tools are now an essential component of the many processes of document preparation on campus.

There are legitimate demands for additional support for campus administrative functions. Computer network and data-base technology are evolving in ways that allow new and more efficient ways to conduct the institution's administrative work, and we need to take advantage of every opportunity to improve the efficiency and effectiveness of these functions. Computing is a strategic technology to University operation and administration, and further investments are warranted.

3. The U of S Computing Model - Current and Future

3.1 History

Computing technology, applications and the method of user interaction with computers have changed dramatically since the introduction of computers in the late 1950's, when toggle switches were used for programming. The history of computing can be characterized by the following "generations":

- Batch processing. Programs execute in sequence, one after another. Users generally wait a long time for their results, which are usually displayed on paper.
- Timesharing. Many programs share the resources of a large centralized computing facility. Terminals, or personal computers in 'terminal emulation mode', are used to communicate with the computer.
- Distributed computing. This is the same as timesharing, except that several systems, each with its own special functionality, are used instead of one central facility.
- Networked-based computing. A network connects personal computers and workstations to services and resources which are accessed through a very high-speed network.

The presence of new computing styles has not eliminated the use of the "older" computing styles. Older styles continue to be used for the functions that they do best, while the new styles use new technology to provide additional functionality. Even though networked based computing is predominant at our institution, batch processing and distributed computing are also used. This makes our campus computing environment unique in that we do not have a single 'mainframe' system that supports most functions of teaching, research and administration.

3.2 Network-Based Computing

The University adopted distributed computing in the early 1970's. The appearance of Local Area Network technology in the early 1980's provided a natural evolution of our concepts of distributed computing. In 1985, the University adopted a style of computing which today is generally known as network-based computing.

Our commitment to, and vision of, network-based computing was first presented in "Project ACCESS: The Advanced Computing and Communications Educational System at the University of Saskatchewan"[1]. A conceptual view of this computing style is presented in Figure 3.1.

In network-based computing, personal computers and workstations are connected by a local network to college, departmental or work-group servers. The local networks are connected to a campus (network) backbone. The backbone attaches campus-wide services such as computation, database, information, communications and access to external (off-campus) networks. Thus, all campus personal computers, workstations and network services are joined together to form one large campus-wide network. Advantages of this computing style include:

- the provision of a convenient, easy to use and consistent communication medium.
- greater sharing of data and other resources. Users may use the network to access many kinds of resources, either local to their work group, on campus or from other institutions in the world.
- transparency of access. The use of network services such as printing, database access, common applications, or high performance computing, appears almost as if they were local to a campus user's workstation, personal computer, or terminal.
- lower costs of expansion. Computing functionality can be added in a "modular" fashion as needed and at an incremental cost. The computing "modules" can be managed, supported and accessed by all campus users, regardless of their location.

The University of Saskatchewan is a leader in network-based computing. We were the first in Canada to adopt Ethernet (both coaxial and fibre-optic) on a campus-wide scale, and are among the most advanced users of that technology. The University has the largest Ethernet network in Canada and one of the largest in North America. The functionality and performance of Ethernet has been

[1]Kavanagh, Robert N.; "Project ACCESS - The Advanced Computing and Communications Educational System at the University of Saskatchewan", University of Saskatchewan, December, 1984.

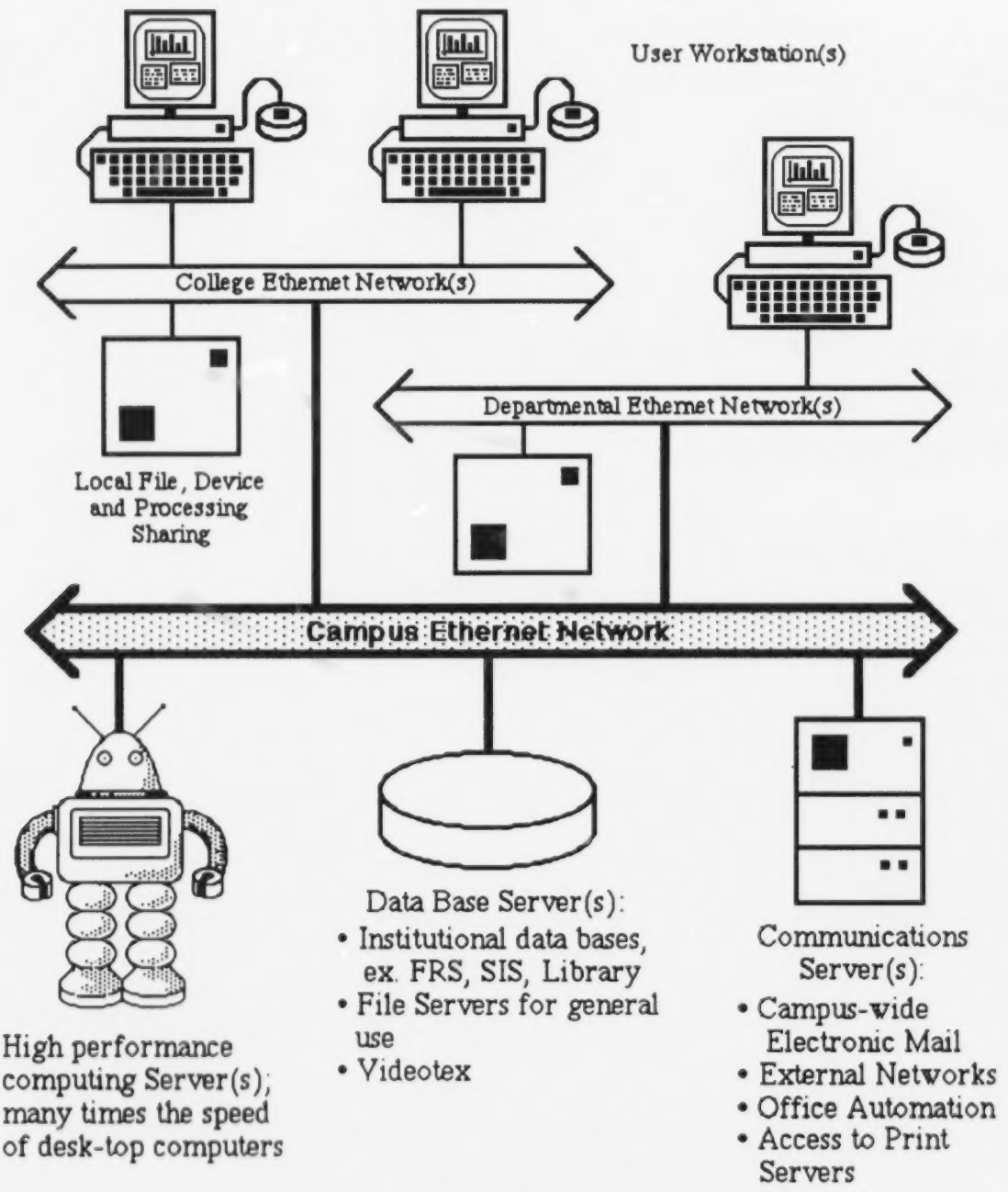
User Workstation(s)
College Ethernet Network(s)
Departmental Ethernet Network(s)
Local File, Device and Processing Sharing
Campus Ethernet Network
Data Base Server(s):
• Institutional data bases, ex. FRS, SIS, Library
• File Servers for general use
• Videotex
Communications Server(s):
• Campus-wide Electronic Mail
• External Networks
• Office Automation
• Access to Print Servers
High performance computing Server(s); many times the speed of desk-top computers

Figure 3.1 A Conceptual View of the Network-Based Computing Model at the University of Saskatchewan

very satisfactory, and we will continue to evolve this style of computing with further use of the existing technologies and migration to new technologies like FDDI[1] and OSI[2].

3.3 Information-based Computing

The 1990's are seeing the emergence of a new computing style, which might best be called "information-based computing". Information-based computing is a natural extension of, and depends upon, network-based computing. It is a continuation of the shift in emphasis from centralized facilities to the user's desktop applications. Unlike previous computing styles which were primarily technology-based, information-based computing will see computers become vital tools for communication, and for information access and sharing. The Senate Computing & Communications Committee at Queen's University calls this computing trend "**Client**-Centred Computing"[3]. They say:

> "As networking, application, and **client** interface standards mature and come into general use and the range of information resources grows, the computing and communications system will fade into the background as the focus shifts to its ultimate subject, the client. ... Improvements in areas of Artificial Intelligence such as Expert Systems, Natural Language Processing and Image Recognition will enable the workstation to become a personal helper assisting in information gathering, analysis and presentation as well as a wide range of personal management and communications tasks".

The committee calls the specific instance of client-centred computing in academia as "scholar-centred" computing. The extension of this notion to other clients, for example management, can yield another instance which could called "management-centred" computing. The point is that in the future, computing is going to become less obtrusive and more a personal assistant to knowledge workers in all aspect of teaching, research and administration. This point is demonstrated in the video "Knowledge Navigator"[4]. The video shows a professor using a notebook-sized computing device with full colour video, speech output, natural language understanding and expert system capabilities. Many of the capabilities demonstrated in the video are now available in research labs and will start to appear in systems during the coming decade.

In information-based computing, users have easy and transparent access to a variety of information services from campus or from their homes. Some characteristics of information-based computing include:

- Workstations
  - widespread use of powerful workstations with audio and advanced visual capabilities (in place of the relatively primitive personal computers of today).
  - easier to use (human oriented) interfaces, e.g. graphical, pointing and voice.
  - a workstation will become the "window" to network-based, information and computation resources.

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[1] "*Fibre Transmits Strategic Advantage*", Information WEEK, Sept. 25, 1989, pp 48-52.
[2] "Open Systems Interconnect", or OSI, is the emerging international software standard from the International Standards Organization, for communicating among systems in a network.
[3] "Towards a Strategy For Computing at Queens", Senate Computing & Communications Committee, Queen's University. June 12, 1989.
[4] Apple Computer, Inc., Cupertino California

- Services

  - increased accessibility of information and communications services.
  - easy access to integrated data, text, graphics, audio and video information.
  - continuing need for workstation support services such as common applications, file backup, distributed printing and remote program loading.

- Networking

  - network access from most campus offices, labs, and classrooms.
  - increased dependence on external networks, both from the metropolitan area of the university community into the campus and from the campus to world-wide networks.
  - greater ease and transparency in accessing network-based resources.

Additionally, we can also expect to see a greater availability and use of discipline specific tools, better integration between applications and general use of applications such as imaging, visualization, multi-media, voice mail, expert systems, natural language processing, computer assisted application design, visual databases and simulation.

Network-based computing is a prerequisite to information-based computing. The University's early commitment to network-based computing will make it easier and less costly for us to evolve to information-based computing than for others who are only now just beginning to base their computing on networks. In fact, our vision in network-based computing included access to information and communication services - the basis of information-based computing. The University's on-line library catalogue and bibliographic search services are examples of information-based computing which have already been available on campus for about two years.

3.4 The Campus Ethernet Network

The University of Saskatchewan believes that the campus network is its most important computing resource. Our networking project consists of building a campus backbone which will connect together approximately 30 buildings, and all offices, laboratories and classrooms within these buildings. Any resources or services located on the network are accessible, passing security considerations, to any student, faculty member, researcher or staff member. The current campus Ethernet network , in rough topological terms, is shown in Figure 3.2.

[Figure 3.2 not completed at this time]

Our network is now about 60% complete. Twenty campus buildings are connected (at varying degrees of completion within each building). There are approximately 3000 campus client connections (personal computers, workstations and other communications equipment), public dial-in ports for off-campus connections and over 40 'host' computers on the network. Network usage continues to grow dramatically. In the two years from 1988 to 1990, network utilization[1] has grown at an annual rate of over 100% per year. Currently the campus backbone network transports approximately 32 billion characters of information per week. This is equivalent to approximately 100,000 300-page novels, or 250,000 128-Kbyte floppy disks, or 1600 20-Mbyte hard disks, every week.

The campus network is also used to gain access to external networks such as USENET and NetNorth. USENET and NetNorth are networks of world-wide academic and research institutions

[1] As measured in the number of characters transmitted.

They support electronic mail, data base access and file transfers among faculty and staff at member institutions. This year, we expect to join the CA*net network, initially sponsored by the National Research Council, and which will likely replace NetNorth as the principal academic network in Canada. CA*net will also be a "gateway" to major U.S research and academic networks such as NSFnet, and the 'Internet' which links many academic networks in the United States. This will greatly enhance our ability to maintain electronic contact with other academic and research institutions in Canada as well as in other countries. External network support is essential to an institution such as ours, which is otherwise remote from the major sites of research and industrial development.

3.5 The Economics of Network-Based Computing

Computing at this university, as at other institutions, is characterized by increasingly powerful "personal computer devices"[1] attached to a high-speed network. This computing model is demonstrably effective,[2] and the paradigm of choice at the University of Saskatchewan. We fully expect that the networked workstation model will continue to be the paradigm of choice as the most cost-effective and functional model for growth in computer support. Workstations will still require access to centralized services, so continuing investments in centralized servers, along with that for the personal workstations, will still be required.

The capital cost of delivering computing function to a campus desktop has been relatively constant for over a decade - about $10,000 to $15,000 per desk. Ten years ago, the cost consisted of approximately $1200 for a network connection (a point-to-point connection at speeds less than 2400 bits per second), $1500 for a 'dumb' terminal and about $8,000 to $12,000, per user, for mainframe facilities that actually performed the computing.

Though it may seem surprising, we still spend about the same total amount per desk. However these costs are distributed quite differently: about $1400 for a network connection (for 10 Million bits per second access to a campus-wide Local Area Network), $3,000 to $10,000 for a personal computer and $2,000 to $5,000 per user for network 'servers' (the shared printers, file and data-base servers, communications servers and high-speed computation servers that are accessed over the network). In the typical case, we still spend about $11,000 per desk, with most of the cost occurring in the provision of a personal computer on each desk. In specialized cases (Engineering, Computing Science and the Natural Sciences) the desk-top device can be up to $50,000, or in some very intensive applications, up to $100,000 per system.

Obviously our total hardware costs for computing have risen in the last decade, even though the costs per 'desk' have remained about the same. The reason is that today we have over 3000 desk-top devices compared with only about 500 a decade ago.

3.6 Support Structures for Networked Computing

In order to facilitate and support the style of computing that we encourage for the campus, we need to pay special attention to the structures within Computing Services that deliver technical and applications support. Computing Services has gone through the shift from 'batch' to 'on-line' computing, and that is now to be followed with a shift to 'distributed data bases' and 'workstation-oriented' computing. This creates the need to continually evolve the organization of Computing

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[1]Personal computers, or workstations. The vast majority of campus computing resources - CPU power, disk space, or printing capabilities - are found distributed in offices and not at central facilities.

[2]Kavanagh, Robert N., Andrew, D. F., Custead, L. R. and Pokraka, E. S.; "Applications of a Campus-Wide Apple LocalTalk Network Layered on Ethernet", Minds in Motion, a collaborative publication between York University and Apple Canada Inc., Fall 1989, pp. 59-65.

Services, so that the client support needs in this changing environment can be best addressed. We can expect new organizational structures within that department as the support responsibilities change throughout the coming decade.

3.7 Summary - the Vision of Future Campus Computing

In this section we have tried to present an understanding of the continuing evolution of campus computing 'style'. This evolution will not be abrupt or discontinuous, but it has been, and will continue to be, dramatic.

The fundamental point of reference for future computing and communications on campus is a desk-top workstation that is connected a high-speed network. The network will deliver, in increasingly easy to use fashion, a very rich spectrum of services and tools to the campus knowledge worker. As mentioned on several occasions, the desk-top device will become a 'window' through which information, computation and communication services are provided to the network client.

We now turn to discussing the specific areas in which we need to invest, over the next few years, to achieve this vision.

4. Specific Campus Computing Projects Recommended for the 1990-1993 Period

The presentation in Appendix I provides an overview of areas of desirable investment in computer systems on campus. In this section we focus much more specifically on some particular projects that should be immediately considered. The following descriptions are for a set of projects that Computing Services has identified as particularly important areas in which to invest at this time. As noted earlier, this list is offered as a point of discussion on campus, to stimulate ideas about these and other projects, so that we can, as an institution, finalize a strategic plan for computing investment and development for the next few years.

The projects listed here are, in the opinion of Information Technology Services and the management of Computing Services, the fundamental areas of priority for computing and communications support on campus. Regardless of the amount of support we obtain from industry, we must be working in the areas described in sections 4.1 through 4.6. On the other hand, when potential industry partners realize that these are our priorities, they will also realize that if we have any resources at all, they will be assigned in these areas, or to whatever list of priorities become the institutional plan. Thus the ultimate list of project areas constitutes an important message, both internally and externally.

4.1 Enterprise Networking

The campus network is the platform upon which all other computing activities are built. It remains our most important computing and communications facility. In the next three years, it is desirable to do the following:

- complete the installation of the campus 'backbone' network, with fibre optic cabling interconnecting all of the major buildings, and with intra-building distribution systems such that all faculty and staff offices can be connected to the network, if requested.

- install FDDI technology as the next step in the evolution of the inter-building backbone system, starting with high-traffic areas of campus such as in the computer room sites.

- develop and install a 'Network Management Centre', which will provide management, control, capacity planning and trouble-shooting support for the campus Ethernet and interconnecting networks.

- conduct research in network traffic characteristics, capacity utilization, protocol performance, etc., on our campus network. As a large Ethernet with many clients, hosts and protocols in use, the campus network affords a great opportunity for study of Local Area Network behaviour.

- install the necessary equipment and software to connect a regional network in the Province of Saskatchewan to the national CA*net network.

- develop or acquire software, for use by students and staff from their computing devices at home or at other off-campus sites, which improves the ease of use and functionality of accessing the campus network and its resources.

- explore the use of ISDN[1] technology. The University, through its current use of Northern Telecom SL-1 equipment in both the campus and the University Hospital, is in an excellent position to demonstrate the use of this exciting new technology in telephone service. We could use it to interconnect the two existing SL-1 switches, as well as to experiment with off-campus access using ISDN technology.

- explore the use of Computer Integrated Telephony. Currently a proposal to use telephone-based student registration is being developed by the Registrar's Office, as the first application of this combination of computer and telephone technology. We expect other applications to follow, such as access to the Library and inquiry into other campus databases.

- continue to pursue and adopt standards such as the OSI protocols, X400 electronic mail support etc., as they become available.

4.2 Functionally Integrated Services to Personal Computers and Workstations

The network is the enabling technology that supports all of our computing applications. It enables clients - users of personal computers and workstations, to access a variety of network services that enhance the function of the desktop devices. Even though the University has made significant progress since 1985 to provide new, functional and integrated network services to clients, more work must still be done. The list of desirable developments in this area would provide:

- additional computation, printing, remote boot-strap, file back-up, common application, and data base services for networked devices.

- 'name serving' for campus-wide, distributed, electronic mail services.

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[1] Iffland, Frederick C., Norton, Glenda D. and Waxman, Judy M.;"ISDN Applications: Their Identification and Development", IEEE Network Magazine, Sept. 1989, pp. 6-11.

- investigation of the provision of voice mail, multimedia (video), page layout, and other network multi-modal 'document' services.

- additional information services, such as the library card catalogue and extension of the Library "INFOACCESS"[1] services currently available.

- access to external networks such as NetNorth and CA*net.

- the development or acquisition of software to make the use of a desk-top computer as a 'window' on the world of information services, both on- and off-campus, as easy as possible.

- more focus of Computing Services support resources on this style of computing.

- recommendations and support for a small number of standards for workstation operating systems, user interfaces, network protocols, application development tools, communications, personal productivity tools and electronic document storage. The standards must facilitate the functionality and integration of applications.

4.3 Library Systems and other Electronic Data Bases

The GEAC Library system, now 5 years old, is at the stage where it should be considered for replacement. The current system has reached its limits of capacity and additional functions of Library-related information are desirable in order to continue to facilitate access to the important resource that our Library represents. The Library currently has a task force reviewing the requirements of information services that it should seek to make available in the 1990's.

The U of S Library has pioneered a type of information service that is getting attention at other universities. The Library has a computer-based service called INFOACCESS, which allows on-line access to several popular 'abstracts' data bases, such as ERIC, Psychological Abstracts, Government Publications Index and others. This service is a very cost-effective alternative to having hundreds of faculty and staff purchase individual copies of these data bases and continue to pay for update services. This concept is a forerunner of the future university library, where more and more information is distributed in electronic form. It is an exciting demonstration of the cost-effective use of electronic, network-based, information access.

In the library area, we should achieve the following objectives:

- replacement of the GEAC system in 1991 with a new system that can carry the Library forward into improved information services for its clients.

- continued expansion of the INFOACCESS service, with additional data bases.

- integration, from a user's point of view, of the interfaces which are seen on various Library information services.

In the area of general information data bases, the following projects should be undertaken:

- acquire additional information data bases and make them available on the network.

- select a recommended standard (or standards) for electronic document storage, retrieval and interchange.

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[1]Online, electronic bibliographic data base service available on the campus network.

- develop guide-lines for the creation of campus-wide information servers, and have Computing Services assist in their establishment.

4.4 Educational Computing

The world is poised on the edge of widespread use of computer technology for education. Some might say that this statement has no credibility because computer people have been making similar claims for twenty years. The problem with the last twenty years, so far as computer-based instruction is concerned, is that the tools that were available to produce computer-based instruction were so difficult to use that they required very specialized training, and many hours of work, to produce one hour of instructional material. Statements of 300 to 500 hours of specialist time per hour of instructional module have been common. Now we see a fundamental change in this area. New tools on desk-top computers, such as 'Authorware'[1], have made it possible for content specialists to develop instructional materials much more rapidly than in the past. Claims of authoring time being only one tenth of what it was in the past, are now being made. Further, these new tools allow for the combination of text, live action video, sound, interactive video disk and other 'information bases', to be accessible to the course developer in any given subject. We can expect to see significant development of computer-based educational materials as the cost of the underlying technology continues to decrease and the effectiveness of the tools continues to increase.

It is important for the University to stay abreast of, and to take advantage of, these and related developments. The following projects are identified to improve our usage of computer-based education:

- establish a multi-media development centre, including hardware, software and support capability, so that faculty have access to equipment resources and support to consider development of course-ware that is computer-based.

- identify particular subject areas, and develop computer-based courseware in those areas, using the new tools for multi-media development.

- expand the use of electronic mail and conferencing for student - faculty communication

- acquire and make available educational resource materials and data bases that students can access over the campus network.

- extend campus educational services to the Province, through the SCAN[2] network. As is the case throughout North American universities, we must support distance education and our alumni's needs for 'life-long learning' through computer-based learning resources that are accessible off-campus. This could be a future service to all alumni, provided on a cost-recovery basis.

- focus some of Computing Services and Division of Audio-Visual Services staff resources in support of computer-based teaching.

4.5 Research Computing

[1]Petruk, M.W., University of Alberta, product endorsement for 'Authorware Professional', Authorware, Inc., 8500 Normandale Lake Boulevard, Ninth Floor, Minneapolis, MN 55347.
[2]Saskatchewan Communications Advanced Network.

As has already been discussed, the research community at the University depends heavily on computing. We can expect legitimate demands for computation support to grow in many areas of research. Our objectives in this area are as follows:

- to establish membership in the CA*net national network, which will stimulate collaborative research among Canadian universities, industries and national research laboratories.

- to acquire and support a high-performance computing system. This system will be attached to the campus network and support users with compute-intensive applications. This does not mean the acquisition of a 'supercomputer', but rather the acquisition of a moderately priced, high performance system - commonly referred to as 'mini-supercomputers', which are becoming popular, low-cost alternatives to 'supercomputing'. Our objective should be at least an order of magnitude of performance increase over the currently installed VAX 6000 systems, for scientific computation.

- to increase staff support for high-performance workstations as platforms for research in a number of disciplines on campus.

- to explore the use of FDDI technology for direct attachment from specialized workstations to computation servers and data storage systems.

- to replace the VAX-11/785 computer in the Earth Sciences Computing Facility with a system that is based on current hardware and software technology.

- to stimulate cooperative development, between the Library and Computing Services, of increased capability to access data bases that are of interest to the various research areas on campus.

- to increase the support for digital imaging and its applications, an area of computer use that is expected to grow rapidly in the near future. Digital imaging applications exist in Medicine, Engineering, Natural Sciences, Mathematics, Agriculture and other areas.

4.6 Administrative Support

As has been mentioned earlier, the University is critically dependent upon computer support for administration of its daily operations. There is tremendous pressure to do more with less, to provide new and improved administrative services, to allow wider access to on-line institutional systems such as FRS and SIS[1] and to generally provide a richer and more timely set of administrative information in support of operations at the departmental, college and institutional levels. In this area of computer application, the following are specific objectives:

- to obtain, learn to use and apply modern tools for development of administrative systems. Modern software development environments such as CASE[2] make it

[1]Financial Records System and Student Information System. FRS is a system purchased from Information Associates, along with the Human Resources System, or HRS. SIS was developed by Computing Services.

[2]Computer Aided Software Engineering. These tools are very promising, but require a significant amount of time to learn to use effectively, and substantially more machine resources to run production systems that develop from use of the tools. On the basis that computer hardware is less expensive than people resources, the overall gain in productivity is positive.

possible to design, implement and maintain large software projects more quickly and with fewer staff resources than the older generation tools.

- to increase the staff support for Administrative Applications in Computing Services. Unfortunately our current staff support is very small and the support is spent on just barely keeping current systems operational. We need additional resources if we are to avoid a serious gap between legitimate needs and the ability to deliver and maintain systems.

- to establish a more objectively based decision-making system for assigning resources to administrative systems developments. A proposal, based on a similar move at the University of Western Ontario, is currently being developed[1] for use at our University.

- to expand the computer hardware facilities to support wider access to SIS and FRS, or their equivalents, in the future.

- to determine an administrative data base strategy for the University and a complementary strategy for developing transaction processing with such data bases. In the light of developments in distributed data base technology, and the emergence of applications development tools to access such data bases, we have to examine systems such as SIS, HRS and FRS to determine if they can continue to be the platforms for these administrative functions an the University, either in their current forms or with some modification or replacement.

- to examine the use of Computer Integrated Telephony as a support tool in administrative applications.

- to facilitate the development and acquisition of College and Departmental administrative applications.

4.7 Summary of Recommended Project Areas

Each of the areas above needs to be examined in more detail. Cost estimates need to be developed and priorities established. However, before going to that next step in the process it is important to have the ideas reviewed in their current form, to at least establish that these areas are generally supported, across campus, as the key directions for future computing activity on campus. The implications of even these few areas are immense in terms of steadily improving the campus computer support for teaching, research and administration. The need for continued investment is real, justified and critical. Hopefully the review of these suggested project areas will produce an 'institutional convergence' on a committed plan for action.

5. Funding for Computing and University-Government-Industry Partnerships

Throughout the previous sections of this document we have shown how critical computing and communications are to a modern university, and that this dependency will increase as we move into the 21st Century. In this section we take a look at the realities of funding required if we are to make

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[1]Kavanagh, Robert N., Jones, Dean.C. and Eaton, Robert B.; "A Process to Assist in Determining Priorities for Administrative Information Systems at the University of Saskatchewan", (in draft form), Office of Information Technology Services, February, 1990.

adequate progress to attaining the goals set out in sections 4.1 through 4.6, and to future goals that will develop.

It will be seen that the financial challenges are significant. On the Capital side, we need, in perpetuity, a minimum of the kind of funding that the Province generously provided through the URDF program in 1985-88. In terms of Operating Budget, a strong case has been made[1] for increasing the staff support in Computing Services by 20 to 50 people over the next decade, with an immediate increase of approximately 10 people. In addition, funding is required for approximately 10 staff positions to support undergraduate computing laboratories in the Colleges. Unless we can address these funding challenges, our future as a modern University, capable of meeting the needs of our total provincial community, will be in jeopardy.

We present in the remainder of this section some background on the estimated increases in required investments for computing and conclude with suggestions that we vigorously pursue partnerships with government and industry.

5.1 Increasing Dependency on Computing and Communications Requires Increasing Investment

5.1.1 Capital Investment Required for Computing at the University

In a previous document[2] there was presented a comprehensive analysis of the capital investment requirements for computing and communications facilities on campus. That document showed that our requirements for investment were distributed as shown in the following diagram. Note that the analysis referenced did not consider in detail the implications of a program of activity such as described in section 4. However, based on our history of recent expansion, our capacity to deploy and use new systems and on current trends in technology costs, we believe that the graph below is a reasonably accurate depiction of what is required, as a minimum, for continuing investment in computer and communications facilities.

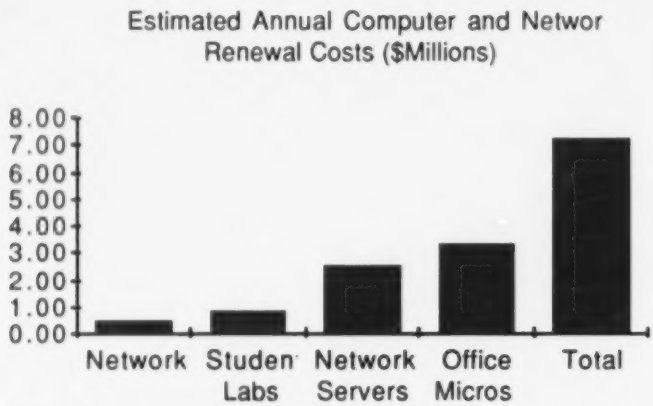


Figure 5.1 Estimated Annual Investment for Renewal of Current and Projected Inventory of Computer Hardware and Software

The total estimated annual capital costs shown in Figure 5.1 comes to about $7.2 Million. The analysis in the earlier document went on to suggest that although the capital requirements appeared

[1]Jones, D.C. "1990-91 Budget Submission for Computing Services", University of Saskatchewan, February, 1990.
[2]Kavanagh, Robert N.;"Project ACCESS - The Advanced Computing and Communications Educational System at the University of Saskatchewan: Three-Year Progress Report and Recommendations for Future Developments", University of Saskatchewan, November 1988.

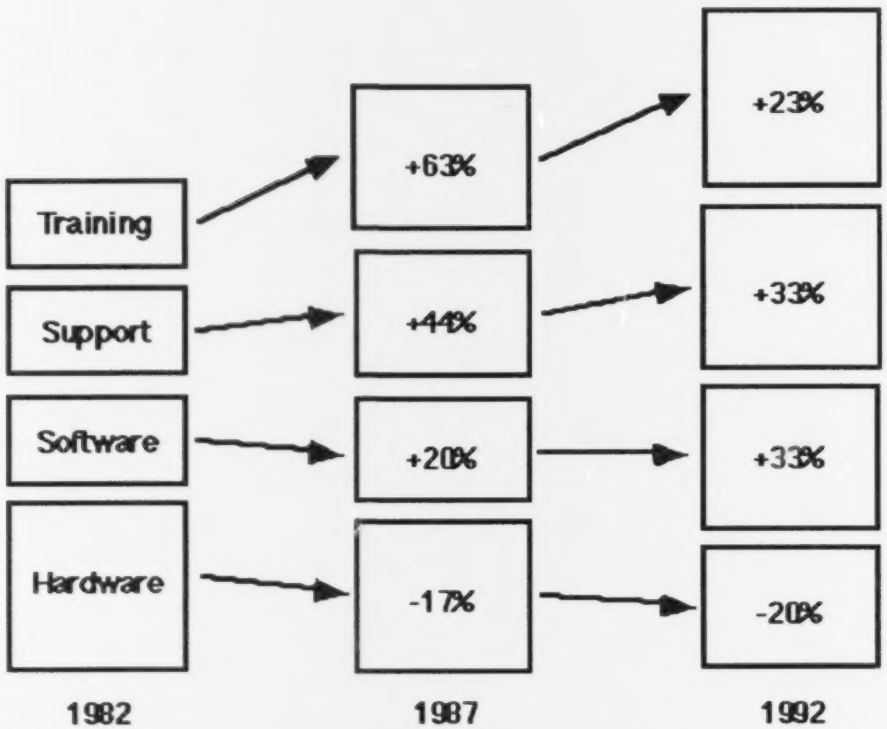
beyond our capacity, there are some reasons for optimism. First, the estimates are based on list prices for the equipment; we normally obtain some discounts from manufacturers. Second, it was noted that the University currently appears able to spend about $3.0 Million annually on computer and related purchases, based on spending history over the period 1985 to 1988. Therefore our 'shortfall' is currently about $4 Million annually. We need to achieve part of this through additional funding and part through allowances from industry. We have every reason to believe that if the University and the Province can arrive at a basis for additional funding for computing and communications, to a level increased by about $2,000,000 annually, the opportunities for significant partnership agreements with industry will follow. As a consequence, our ability to achieve the kind of environment described in section 4 would be greatly enhanced, at least in terms of facilities.

5.1.2 Pressures for Increased Support for Computing

One of the myths about computing is that 'computing is costing less'. The statement is often made by people who are considering the declining costs of computer hardware, particularly personal computer hardware. It is true that the hardware component of computing costs is declining in relative terms, but the total costs for computerization in any organization are increasing. The reason for this is the increasing cost of software, support and training. As systems become more powerful and can handle more sophisticated applications, the need for support is growing. Notwithstanding the increasing ease of use of software, the average user is putting more and more software on their systems and thus the net support requirement is growing. Consider the diagram on the following page, taken from Microsoft Corporation estimates on the history and trends for total personal computing costs. Between 1982 and 1992, they are estimating a 34% decline in hardware costs for a personal computer, but an overall increase in costs of about 37%. Because the hardware costs are decreasing, we are in a situation of being 'trapped' by the attraction of declining costs of the requisite hardware, only to discover that, after a system has been on a desk for a time, further productivity gains are not possible unless there are significant increases for training and other support. The problem for our university, and indeed most public sector organizations, is that the increasing pressures for training, support and software purchase are not being met with realistically increasing resources for meeting those needs.

Costs of Personal Computing

(from Microsoft Corp.)



To illustrate the cost picture another way, it is reported in a study during 1986-87[1] that the average annual costs of operating a personal computer in large organizations was $18,000 US, per machine, broken down as follows:

Category	Costs	Percent of Total
Hardware	$3,300	18%
Software	1,650	10%
Support & Training	12,750	70%
Data Access	300	2%

Few, if any, in the university sector, would have experienced the kind of support that this report is describing. We operate in a mode where people scratch funds from their research grants, departmental operating budgets, university capital funds and perhaps even their own private pockets, to purchase a personal computer and some software. After that, for the most part, we leave them on their own! The Nolan and Norton report goes on to claim that if personal computer support is addressed as a 'strategic business vision', not merely a 'technology-driven vision', the return on investment in large organizations can be as high as ten-fold!

[1] "Managing Personal Computers in the Large Organization", A Report Prepared for Lotus Development Corporation by Nolan, Norton & Co., Dept. of Research, One Cranberry Hill, Lexington, Mass., 1987.

It is not clear how claims such as are contained in the Nolan & Norton report can be applied to a university setting. However, we believe that the Microsoft estimates, and the report, confirm our own experience at our university:

- computing support requirements are growing, and growing much more rapidly than underlying support resources. The divergence between these two is referred to as the "Support Gap Crisis[1]", and is being felt at universities and other large organizations.

- while hardware costs are declining, the overall costs of computerization are increasing, as more and more clients acquire more and more applications which require support, integration with other systems and training.

- the vision of clients using powerful desk-top systems, in an environment of network-based services, is clearly one which requires much more attention to the needs, individually and collectively, of those clients.

In summary, computerization can bring significant benefits to a university or other large organization. But unless we make support for computing part of a 'strategic business vision', the benefits are limited to whatever modest productivity gains are eked out by tenacious individuals who are willing to train and support themselves. It is clearly difficult to increase support resources to the levels reported in 'corporate North America', but unless we do our best to address this challenge for more and better support, the benefits we derive from purchasing hardware will be greatly diminished.

As has been mentioned previously, we estimate that the necessary growth in staff support resources, over the next 10 years, is a total of 20 to 50 people in the Department of Computing Services, approximately 10 additional staff in the colleges, in direct support of student computer laboratories and an unknown, but large number of computer support staff directly employed by departments and colleges. The immediate requirement is about 10 people in Computing Services, 10 staff in student laboratories, and about 10 people in various support roles in the colleges and other units. While this requirement may seem hopelessly unlikely to be fulfilled, there is no point in pretending it is not the real need.

5.2 Shared Costs and Benefits in University-Government-Industry Partnerships

It is very clear that computing demands will continue to put very severe strains on university budgets, probably forever. The University of Saskatchewan cannot itself hope to handle the costs implied by the capital and operating estimates presented here. At the same time, we cannot ignore the strategic importance of computing to the University, its faculty and its students.

If we are going to make any meaningful headway in building and maintaining the kind of computer and communications environment that is contained in the vision of section 3, it is imperative that we seek outside support. We must form an alliance, with government and industry, to try to obtain their assistance in going beyond what we could achieve with the modest resources at our direct disposal. In addition, we may have to consider extraordinary ways to obtain financial resources through tuition surcharges to students and an overhead levy on research grants and contracts.

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[1]Yeates, J., President of ComputerLand Canada, in a presentation "The Second Generation - Micro Integration", ComputerLand Business Show, Toronto, 1989.

However, we must not underestimate the value of what we bring to the table as we pursue partnerships with government and industry. Much of our computer-based research is of direct benefit to the Province, and thus can justify special investments in computing from government coffers. In addition, the highly trained faculty and staff, when properly equipped and supported, are capable of making significant developments in many areas of teaching, research and administration, such that the outcome of their work is of interest to the computing and other industries. In short, we can produce an impressive list of 'deliverables' if we are given the opportunity to enter into such partnerships.

Canada's competitors in world markets are taking a very aggressive approach to joint university-government-industry projects which focus on strategic initiatives in research and development. We can not do less, if we mean to enhance or even preserve the standard of living of our future provincial community.

6. Summary

Computing support is strategically important to the University. Our ability to serve the province and its citizens in the future is intimately dependent upon our ability to generate, organize and make accessible new knowledge in many fields. We expect that every academic discipline will become increasingly dependent upon computer-based information processing and dissemination. If our students are to achieve their fullest potential, it is imperative that we continue to invest in modern information processing tools and providing the widest possible access to campus information resources.

For a University such as ours, in a climate of need in so many areas, this is yet another great challenge. We have set ourselves such challenges for computing before, such as in the development of Project ACCESS in 1984. That project saw us achieve a tremendous improvement in computing resources and systems over the period 1985-1988, and the challenges then were no less daunting than now. In reviewing the goals and objectives for ACCESS, an IBM Canada senior executive made the following observation[1]:

> "This is a challenging, but realistic plan. It may be beyond your grasp, but it isn't beyond your reach".

It's important to reach. A commitment to less than excellence is a commitment to mediocrity. Hopefully this document will serve to clearly state the needs for computing development, and to set targets for us to reach for, in the early 1990s.

[1]Personal conversation with Mr. Graham, then IBM Canada Manager of Cooperative Development, 1985.

Appendix I - Strategic Areas for Computing Development on Campus

I.1 Background

The Department of Computing Services is attempting to move to an annual process of planning for computing developments, in a context of 'strategic' decision-making about computing. Steps are being taken to establish this method of planning for computing in all areas of computing applications: teaching, research and administration.

At the present time, we have to acknowledge that the campus is not coming from a tradition of formal 'strategic planning' for computing, although we have made a number of 'strategic' decisions, such as the 1985 decision to build a campus-wide computing network. This means that there is no existing process, or organizational structure, in which to vet ideas for computing directions, in the context of 'strategic planning'. Notwithstanding that fact, and setting a goal to indeed have an on-going, regular, representative process of strategic planning for computing, we have to begin, somewhere.

In early September, 1989, some of the Computing Services management team participated in a visit to Digital Equipment Corporation in Massachusetts, at the invitation of Digital. We were invited to participate in a 'Corporate Visit', which is an intense review of questions raised by the customer about Digital products, both present and future, directions for product evolutions, new application areas, better tools for using existing technologies, programs for cooperative development with universities, etc. This visit caused a considerable deal of reflection, on the part of Computing Services management, about future directions for campus computing, not only with products from Digital, but with technologies from other manufacturers that can work well in our network environment.

During the Corporate Visit, it was confirmed that there continues to be potential for cooperative development between the U of S and Digital Equipment Corporation and the Canadian subsidiary. However, as noted in the introduction, the process of securing industry-university partnerships is much more competitive than it was in 1985, and the industry is looking for more tangible benefits from investment in universities. In order to identify the potential in more detail, the Saskatchewan Digital team offered to bring in Mr. Jan Wall, the Information Systems Consultant from the Digital Calgary office, to lead Computing Services management through two days of review of computing directions on campus, so as to identify where there might be areas of overlapping interest. This review took place on September 19 and 20, 1989.

It is fair to say the these recent opportunities to think about future directions for campus computing have been intense, wide-ranging and very worthwhile, but flawed. The shortcomings of the discussions that took place in September have to do with scope of involvement of other parties who have a keen interest in campus computing. This includes not only participation by campus personnel outside of Computing Services, but also contact with other vendors. However, we can thank Digital for 'forcing' us to get as far as we have in a short period of time, and we believe that the material that is presented here is well based. What we have to do, and are attempting to facilitate with this document, is as follows:

- present to the campus a list of suggested areas for future developments in computing, so that it can be discussed in a representative setting, modified, prioritized and set into a concrete plan.

- identify other potential industrial partners in the development of new computing applications on campus.

I.2 Suggested Areas for Future Computing Development

In this section we present, in alphabetical order, a list of areas of computing development, that the management of Computing Services has identified as being 'strategic', or at least 'important' to the campus. The list is certainly not a complete set of possible areas for computer development on campus, but it is a very comprehensive and wide-ranging set of topics. As this list is reviewed by other campus readers, it is hoped that the topics outlined here may cause additional topics to come to mind, and to determine specific projects that will be undertaken at campus, college and departmental levels.

Every College and department is affected by one or more of the areas tabulated on the next two pages. Indeed, the size of this list of 'important developmental areas' is merely an indication, and confirmation, of how important computer support is to our institution. What is daunting about the list is the challenge to address even a subset of these areas, in some meaningful way.

Area of Development or Application	Brief Explanation	Enabling Tech'y or Applic'n[1]	Campus Wide or Special'd[2]	Instr'n, Research or Admin[3]
Administrative Applications	The development or acquisition of new administrative systems for the campus; enhancements of existing systems.	Application	Campus Wide	Admin
Compound Document Architecture Applications	A compound 'document' is a digital document that includes text, sound, graphics and video. CDA applications will allow such documents to be created, edited, shared, etc. Initial applications in library materials, Diefenbaker Centre, hyper-media for instruction, etc.	Both	Campus Wide	All
Computer Integrated Telephony	The interconnection of campus voice facilities with computer systems; applications such as telephone registration, library enquiry, fee assessment, general campus information access.	Both	Campus Wide	Mainly Admin, some Instruction and Research
Distance Education	The connection of campus computer-based instructional support systems to external networks, to extend computer support to off-campus students. Also to provide better access to external academic networks.	Application	Campus Wide	Mainly Instruction and Research, some Admin.
Earth Sciences Data Processing	Teaching and Research applications in Geophysics, Geology, Geography, Biology and related studies.	Application	Specialized but wide-spread	Instruction and Research
Enterprise Networking	The building and use of a campus-wide Ethernet network; making network-based computing the norm for all campus computer users.	Enabling Technology	Campus Wide	All
Expert Systems	Artificial intelligence applications; systems that embody the 'knowledge-base' of content specialists, in computer applications for a variety of needs.	Both	Campus Wide	All
Geographical Databases	Organization, storage and access of geographically-based data, such as in Agriculture, Geography, Geology, Engineering and other disciplines	Application	Specialized but wide-spread	Instruction and Research
Graphical User Interface	The shift to iconic interfaces to most computer applications; windowing environments as the common interfaces to campus applications	Enabling Technology	Campus Wide	All

Area of Development or Application	Brief Explanation	Enabling Tech'y or Applic'n	Campus Wide or Special'd	Instr'n, Research or Admin

[1] An area mentioned could either be an 'Enabling Technology', or an 'Application' of a technology, or both.
[2] Some topics would have impact on a campus-wide scale; others are more specialized to particular campus groups.
[3] Areas of potential activity can affect Instruction, Research or Administration, or some combination of them.

Health Sciences	A variety of applications in Medicine, Nursing, Dentistry, Pharmacy.	Application	Specialized but wide-spread	All
High Performance Computing	Access to 'supercomputing', in a form that is cost justified at this University.	Both	Specialized but wide-spread	Instruction and Research
Imaging	Applications of recording, analysis and presentation of high resolution 2-and 3-dimensional images, in monochrome and colour.	Both	Specialized but wide-spread	Mainly Instruction and Research; some Admin.
Instructional Computing Tools	Continued development of computer applications for teaching. Could include, but go beyond traditional 'CAI' applications. Emphasis on improving quality and effectiveness of teaching.	Both	Campus Wide	Mainly Instruction; some Research
Integrated Desktop Computing	Further integration of personal computer applications with campus-wide information and computing services. Continued pursuit of 'seamless integration' of desk-top with other network services.	Both	Campus Wide	All
Library	Development of a plan for replacement of GEAC 8000 system. Study of new computer-based services and functions that should be offered by a university Library.	Application	Campus Wide	Mainly Instruction and Research; some Admin.
Real-Time	Specialized systems for capture and analysis of data in 'real time' of experimental or computer-control situations.	Application	Specialized but wide-spread	Instruction and Research
Software Development Environments, Academic	Acquisition and use of tools to assist development of software more quickly, at less cost, with higher quality. Special needs for the academic programmer.	Both	Specialized but wide-spread	Instruction and Research
Software Development Environments, Administrative	Acquisition and use of tools to assist development of software more quickly, less costly, with higher quality. Special needs for the developer of administrative applications; CASE tools.	Both	Specialized but in several areas	Admin.
Student Jobs Data Base	Development of computer-based system to assist students in finding employment. Support of on-campus Canada Employment Centre.	Application	Specialized	Admin
Training for Computer Users	Continuing development of training modules for campus computing applications.	Application	Campus Wide	All
University Information Base	Development and use of computer-based information about the campus; wide variety of potential applications.	Application	Campus Wide	All
Veterinary Medicine Applications	Continuing development of systems in support of WCVM needs.	Application	Specialized	All